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WHAT RESEARCH SAYS ABOUT INCREASING THE NUMBERS OF FEMALE STUDENTS TAKING MATH AND SCIENCE IN SECONDARY SCHOOL

Increasing the numbers of female students in math and science courses where female participation rates are low relative to male rates has been a goal of educators for thirty years. A major purpose of reducing the gap is to ensure that women do not prematurely exclude themselves from career opportunities by dropping college and university prerequisite courses in high school.

While in recent years the gender gap has been reduced in some of the professions such as medicine and finance, the gap persists in fields such as engineering and scientific research. Also, it is difficult to determine the reasons for the increase in female participation in mathematics,or the relative effectiveness of different interventions, because systematic program evaluation is unusual. This report summarizes research which investigates the ways in which female participation in math and science can be encouraged.

Reasons for Under-representation of Females

Researchers have identified a number of 'reasons' for the different participation rates of males and females in math and sciences. Armstrong (1979) found that even among students who opt for math and science, the motivations for males and females differ. For example, Armstrong (1979) found that girls who pursue math did so because of educational aspirations, males because of parental expectations. This suggests that parents view their sons as future engineers and doctors and project these expectations to them while the girls who intend to continue with their studies beyond secondary school, especially in the sciences, must be more self-motivated. A Toronto Board of Education study (Larter et al, 1982) indicates that both male and female junior high school students usually are not aware of career options or their educational requirements. However, this lack of information would not affect males to the same degree as females because they would take math and science in response to parental expectations. Girls on the other hand, who tend to need an intrinsic reason to take math (e.g. college or university prerequisite courses) would not have adequate information to make informed decisions.

Fox (1976) partially blames the lower participation rate and poorer performance of female math students on the failure of educators to provide a bridge between the theoretical nature of math and important social attitudes of girls. In addition, Fox argues that educators have not made a sufficient effort to bring out the relevance of math to career goals for their female students.

Lantz (1985) feels that the beliefs and attitudes leading to subject avoidance are acquired through rewards (e.g. good grades, approval, getting into university) and punishments (e.g. being made to feel stupid, not getting into university). Furthermore, she argues that future or anticipated rewards have less influence on behaviour than current or past ones because the future is unknown. Tobias (1978) found that females dropped math because it required more work and commitment each year suggesting that for the girls in his sample, the rewards did not justify the effort or more importantly, that no one showed them what rewards were possible.

Increasing Female Participation

Strategies to increase course enrollment can appeal to young women at one or more of three levels: the cognitive (changed beliefs about the usefulness of math); the affective (increased confidence, decreased anxiety); and the ability or achievement level (improved spatial ability/improved grades).These three are closely related, with change at one level often preceding change in the other areas. Lantz(1985) suggests that approaches to change at the affective and achievement levels appear to have more impact on behaviour (enrollment) than those at the cognitive level.

Adult males can play a positive role in bringing about desired attitude changes. Attractive male adults are effective communicators of information in both one-day conferences and long term interventions. In addition, male companions represent a significant influence on the

occupational aspirations and choices of females of all ages and abilities (Safilios-Rothschild, 1979). Another study finds that male high school students are seen as credible communicators by grade eight females, preceded only by parents and female science teachers (Koballa, 1988).

Educators may also learn something relevant from another area in which efforts are made to alter the behaviour of young people; e.g., drug and alcohol abuse prevention. Research shows that programs are not effective when they rely on a "don't do it" approach. They are more effective when the emphasis is placed on the clarification of values and decision making skills which stress the individual's responsibility for her/his future (Lantz, 1985). A Toronto study has shown that it is important to direct interventions at young children 8-12 years of age, when the negative correlation between age and attitudes toward non-traditional work first appears (Herring, et al, 1985; see also Hardin and Dede, 1975). Furthermore, young children are particularly responsive to role playing and hands-on activities especially when they take place within naturally occurring groups--e.g., Girl Guides or Boy Scouts, classes, etc.

It is also important to be sensitive to the fact that math and science will not be appropriate choices for all females just as they are not appropriate options for all males. Herring and her colleagues (1985) make a significant point, that not all females can or want to be doctors or engineers. Even for those who are more scientifically or mathematically inclined, career possibilities in the skilled trades and technological industries should also be presented as viable options. Therefore, to have relevance to the widest possible audience in terms of abilities and talents, a range of possibilities should be discussed, instead of an either/or situation.

Three Kinds of Intervention in Educational Settings

1. **One-day conferences**

   The conference approach to intervention is popular because it is apparently logical, straightforward and recognizes the fact that most young people are ignorant about careers (Lantz, 1985). It has been shown that conferences can increase students' awareness of the usefulness of math (and presumably also science); can decrease sex stereotyping slightly; can stimulate career explorations and may produce changes in intentions or plans (Cronkite and Perle, 1979 and Wirtenberg, 1978). However, other investigations conclude that long-term sustained changes to values or behaviour are difficult to substantiate (Lantz, 1985). That is, conferences may affect beliefs, but not affect course enrolment. This suggests that conference presentations are aimed mainly at the cognitive, or belief level; to create an effect on enrolment, it would be important to make the presenters, material presented, and method of presentation more powerful at the affective or attitudinal level.

   Many conferences are not as effective as they might otherwise be because they incorporate few conditions conducive to bringing about attitudinal changes. The events: usually require neither active participation nor commitment from participants; use threats ("take math or these are the consequences"); and fail to provide alternatives (Lantz, 1985).In addition, the events fail to seriously examine the reasons girls do not take math classes (such as the greater ease of success/grade reward in other courses.)

   The matter of conference presenters has also been examined. These types of events are usually facilitated by women. Because they are usually carefully selected for their expertise and communication skills, invariably they are effective conveyors of information. But they are not necessarily seen as role models by female students. Evidently, adolescent females have difficulty identifying with women in jobs about which they have very little knowledge. Identification with the speaker increases when additional personal information about the speaker is provided (e.g. personal history, wife, mother, etc.). The conference format is usually too limiting for the speaker to convey anything more than basic information. However, over longer periods of time, women can be effective role models; (see curriculum section below). Other research suggests that peers (Trigg and Perlman, 1976) and girls only a few grades ahead (Kahle, 1983) be given more active roles in conferences because they are perceived to be credible communicators by young girls. Similarly, attractive male students and adult male facilitators may achieve the desired effects (but perhaps not

for the desired reasons) (Lantz and West, 1977 and Koballa, 1988).

2. **Staff development**

Students perceive teachers as credible, knowledgeable and concerned about their welfare (Koballa, 1988). Therefore, much effort has been devoted to assisting teachers to create gender-equitable learning environments (e.g. learning materials, how they interact with their students, role playing, assigning of tasks, etc). Research by Mason and Kahle (1988) demonstrates the validity of this approach.In this study, the initial inservice sessions for teachers were followed up with periodic phone-calls and visits as part of a maintenance program. Stallings (1985) identifies a positive relationship between "an active instructional involvement of teachers with students" and enrollment in advanced math classes by females. Conversely, she found a negative relationship between math enrollment by females and classrooms characterized by much discipline and written assignments. There is also evidence of a link between teachers'math achievement and that of their students. Teachers' math achievement is related to the number of secondary and post-secondary math courses which they have taken.

3. **Curriculum**

Another approach involves the modification of the curriculum to include courses such as career counselling, math anxiety clinics, math/science tutoring or gender-segregated classes to encourage females to continue with these courses. However, even when interventions such as career counselling courses are integrated into the curriculum over a longer period of time, they do not always have an observable impact on course selection (Fox, 1979 and Stallings, 1979). It may be that a more refined approach, targeted at the student's peer and adult social networks will achieve more positive effects. For example, some research indicates that interventions directed at a female student's parents, peers, math teachers and counsellors are effective in increasing knowledge and changing attitudes toward math (e.g. Lewis and Prillwitz, 1979 and Koballa, 1988). Also, women who have careers in science have been shown to be effective agents of attitudinal change when part of a longer (two month) program (Smith and Erb, 1986). Similarly, an experimental project examined by Lantz and West (1977) was determined to be successful in increasing the participation rates of female students in math and sciences because of the convictions, commitment and attractiveness of the male project director. It is significant to note that positive attitudinal changes have been seen in male peers who participate in interventions alongside their female classmates (Fennema, et al, 1981).

Math anxiety clinics have been conducted to help students "gain control over mathematics" (Tobias, 1978). Typically about six-weeks in duration, the clinics are run by a teacher and psychologist. The little research which has been done on this type of intervention finds only small gains which may in fact, not be totally attributable to the program (Hendel, 1977). As well, some commentators have criticized this approach which treats math anxiety as a disease and the student as someone with psychological problems (Lantz, 1985).

Another somewhat controversial curriculum intervention is the sex-segregated class. Single sex schools were found to be associated with significantly higher math performance for Grade 8 girls (but not boys) in Thailand (Jiminez and Lockheed, 1989). In North York, however, an experimental program for Grade 11 and 12 students did not produce any significant results on math achievement or attitudes (Sangster, 1988). A California based three-week summer program for gifted grades 5-9 girls achieved greater gains but raises questions about the advisability of segregating students by gender (Kravetz, 1984). An alternative to complete segregation may be to ensure that programs have a "critical mass" or a sizable number of females in math classes (Fox et al, 1985).

The curriculum intervention with the most promising results (although most of the evidence is at the post-secondary level) is that of altering instructional approaches to include: more hands-on activities; greater

emphasis on a "discovery' method of teaching and learning; and the use of real-world problems to teach math concepts, problems which relate math to the solution of social dilemmas, giving it humanitarian value.

Conclusion

Clearly, the literature does not provide definitive unambiguous solutions to the problems of increasing and maintaining healthy female enrolments in math and science. However, some of the general factors which can be gleaned from the research on three types of school-based interventions have been discussed above. These factors have proven to be effective in increasing the enrolment of female students in math and science courses.

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